[Proc. Roy. Soc. Victoria, 25 (N.S.), Pt. I., 1912.]

Art. I.—*Preliminary Notes on the Monchiquite Dykes of the Bendigo Goldfield.*

By F. L. STILLWELL, B.Sc.

(Caroline Kay Scholar and Government Research Scholar, Melbourne University).

(With Plate I.).

[Read 14th December, 1911].

Introduction.

The following notes are the result of an unfinished study of the dyke rocks occurring at Bendigo.

References to the rocks are not very numerous among the literature of this gold field, which is mostly contained in Professor Gregory's Bibliography of the Economic Geology of Victoria (1). They are only occasionally mentioned throughout the publications of the Victorian Mines Department, except in Mr. Dunn's monograph (2) where they are treated at some considerable length, and in Dr. Howitt's petrographical report (3). Elsewhere they have been referred to by Mügge (4) in a review of Dr. Howitt's paper, and by T. A. Rickard in his descriptive papers on the Bendigo field published in the Transactions of the American Institute of Engineers. Rickard (5) has given special treatment to the dykes in his paper on the Origin of the Gold-bearing Quartz of the Bendigo Reefs, Australia. In this paper he gives a number of sketches illustrating the relations of the dykes to the strata. One of these, which is incorrect and deservedly criticised by Argall (6) as being inconsistent with Rickard's stated facts, has recently been copied into Malcolm Maclaren's book on Gold (6) as figure 127. The papers by Argall resulted in the discussion on Rickard's work.

Very little work has been done on these dykes within the last sixteen years, and at the beginning of the present year it was thought that a study of these rocks and their relation to the distribution of gold could be profitably commenced.

General Relations.

The dykes, which are locally always termed "lavas," have been injected into the folded ordovician sediments of the Bendigo field. Mr. Dunn (2) has pointed out that the dykes are found along the course of every anticline, and not in the synclines, and that they are not continuous along the whole length of the anticlinal axes at the surface. The course of a lava upward is irregular, and as it rises through the different levels of a mine it wanders at times both east and west of the actual "centre country," but is seldom far away. So regularly do the lavas follow the centre country that they have been of great service to the Geological Survey in the mapping of these anticlinal axes, and Mr. H. S. Whitelaw (7) has tabulated the surface characteristics of the lavas which are always decomposed and recognised by (1) the trench or gutter caused by their weathering more easily than the walls of the adjoining country rock, (2) their more stable decomposition product, the magnesium carbonate, which at the surface occurs in thin nodules or veins, and (3) the peculiar opaline aspect often induced in the quartz of a reef with which they have come in contact.

Observed in one anticline they are frequently found to branch into two or more lava streams which may or may not junction again at higher levels. At the New Christmas shaft, situated on the Christmas anticlinal axis at Kangaroo Flat, six lavas are met in one small crosscut of 94 feet, revealing the existence of quite a network of streams.

In thickness they average from 9 inches to 12. Three-inch seams are not uncommon, and they range down to thin threads which may die right out. Mr. Dunn (2) records a 5-foot lava in the Great Britain Mine. The south shaft of the New Christmas Mine contains a lava 6 feet thick. A 12-foot lava was supposed to exist in the Bird's Reef Mine, Kangaroo Flat, but has been found to be in part sandstone, and is only 5 or 6 feet thick.

The trend of these dykes, north and south, is remarkably persistent, and they form a parallel system of the "plateau region" type. The parallelism is made particularly noticeable by its coincidence with the direction of strike of the rocks. With this parallelism we do expect to meet them in anticlines rather than synclines, for anticlines are always in a state of relative tension to the synclines, and, therefore, suffer fracturing in the relief of crustal stresses in preference to the synclines. The coincidence of the strike of the rocks and the dykes means that the same kind of crustal stresses have been involved in the folding of the rocks, and in the injection of the igneous material. The main earth movements resulting in the folding have resulted from pressure from easterly and westerly directions. The rock stresses which were relieved by the injection of the dyke material, and which no doubt result in rock fracturing, in part, have developed at a later date from the same direction. I think this instance forms a good Victorian example of Harker's principle of the intimate connection between igneous action and crust movements (8), especially if we agree with T. C. Chamberlain that earth movements are inheritances, and likely to be continued in the same manner at different periods of the earth's history.

The cross-courses on the field which have displaced the anticlines and the slides have resulted from movements distinctly minor to the main ones, and Mr. Dunn has spoken of dyke material filling the cross fractures, but I have not been able to verify this.

In such a parallel system of dykes as this, which has originated from the same magma, we might expect the dykes to communicate across the anticlines at different levels in the crust of the earth. The only possible instance of this that came under my notice was in the Koch's Pioneer Mine, Long Gully (Garden Gully line), where a lava comes from the west at the 1200-foot level, and continues through the upper levels to the surface, but is not found in the lower levels.

The metamorphism of the intruded series by the dykes is extremely slight. Apart from the peculiar appearance sometimes seen in the quartz reefs, noticed above by Mr. Whitelaw, the only evidence I can record is the presence of sillimanite crystals in quartz associated with a lava obtained from the Ironbark Mine.

The penetration of these thin parallel sheets, persistent for miles in length, through a thick series of folded sedimentary rocks, is a fact which is impressive. It has astonished previous observers, and caused Rickard (5) to propound a fanciful theory of dyke intrusion based on an unproved statement that the mobility of the lava is due to superheated steam and not to intense heat. Such was rightly attacked by Argall (6) Mr. Dunn (2) is inclined to imagine the presence of explosive forces. There is little to be gained at present by speculation. The mechanics of dyke intrusion is a difficult subject and one little known. It can therefore be well left to a later date.

The question, too, has been raised as to whether these dykes were channels of supply for lava flows at the surface. Rickard was quite sure that they were, because he erroneously connected the monchiquites with the newer basalt, but Mr. Dunn thought probably not. It is not uncommon to find a dyke stream fading out in the upper levels, and an instance was recently noticed in the Koch's Pioneer Mine, where the top of the dyke was largely a mass of sulphur. The presence of sulphur now implies the presence originally of sulphurous gases which were unable to escape through a vent. In this connection it may be remembered that large black biotite crystals are to be found in the lava in places like Jones's shaft, New Chum line (2), and the Victoria Consols Mine. Small biotites are sometimes seen in the sections of rocks from the other mines. The formation of biotite as a mineral is now known to require either the presence of a " mineraliser " like water vapour, or pressure. Mineralisers would have escaped and the pressure would have been established with the existing surface at the time of intrusion. This helps us to think that these dykes were independent and self-contained intrusive bodies. Yet on the other hand the nearest petrographical allies of these rocks in Victoria, e.g., the King's Quarry rock at Macedon (11), have resulted in very small flows, and any small flow at Bendigo could well have been denuded away.

Petrology.

Chemical Characters.

A rock sample from the Central Red, White and Blue Mine, Sheepshead line, was analysed. This sample was taken from the thicker of the two lavas which occur within a few feet of each other in a small crosscut at the 318-foot level. This rock was chosen because it was found to be very fresh. The analysis made is in general similar to that made by Mr. Frank Stone, quoted in Dr. Howitt's paper (3), of a sample of the New Chum lava in Lansell's 180 Mine.

	I.		II.
SiO_2	40.92		39.32
Al_2O_3	11.34		17.53
TiO_2	6.57		—
Fe_2O_3	.54		3.07
FeO	12.96		9.12
CaO	9.28		10.38
MgO	7.78		8.00
K_2O	1.94		3.04
Na_2O	3.27		2.44
MnO	.13		—
P_2O_5	.51		—
CO_2	2.82	Moisture	2.20
H_2O-	.64		5.10
H_2O+	1.77		
	100.47		99.20

I. Dyke, Central Red, White and Blue Mine, Sheepshead line. Analyst, F. Stillwell.

II. Dyke, Lansell's 180 Mine, New Chum line. Analyst, F. Stone

The Sheepshead line is immediately east of the New Chum line, and these analyses tend to emphasise the minor variations that can be noted microscopically in various samples of the Bendigo monchiquites. The Sheepshead lava is relatively more acid, though at the same time it is a fresher rock. The high titanium content finds expression in the highly titaniferous augite, and the abundance of ilmenite. The low silica percentage, moderately low alumina, moderately high alkalies with soda predominating over potash, high lime, ferrous iron and magnesia are the chemical features of the monchiquite group of rocks.

Petrographical Characters.

Central Red, White and Blue Rock, 318-foot level. (Plate I, Fig. 1). This rock in the hand specimen is dense, bluish-black, and very hard. Porphyritic crystals of olivine can be seen, and also occasional white vesicles filled with calcite.

Microscopically, it is extremely dense. Occasional very large olivine crystals are found which are more or less completely serpentinised. Smaller olivine phenocrysts are common, and are for the most part relatively clear and unaltered. These fresh olivines from the 318-foot level are remarkable when one considers that the olivine usually seen in the Bendigo rock sections is very much altered, even at the deepest levels of the Victoria Quartz Mine, 4614 feet.

Augite is perhaps the most abundant mineral. It is a purple, titaniferous variety, and faintly pleochroic. A brown prismatic hornblende is present in a much smaller amount than augite. It is strongly pleochroic, and is distinguished from biotite mainly by its oblique extinction. The angle between the prism faces can only sometimes be seen.

Ilmenite is extremely abundant in small crystals distributed evenly throughout the rock. Microlites of ilmenite are also abundant. Thin, colourless rods of apatite are discernible in the ground mass.

The ground mass when unaltered is clear, colourless and isotropic. Its refractive index is higher than that of xylol (1.4912) and not much different from that of a sample of cedar oil (1.5090). The ground mass is therefore a glassy residuum, and not analcite. Not only does the material serve as a general ground mass for the whole of the rock, but it appears as well here and there in irregularly-shaped areas which, containing an excess of brown hornblende, form light-coloured patches in the rock. These are obviously the acid residuum remaining after the crystallisation of the bulk of the magma. In part the ground mass is found to be not absolutely isotropic and to show polarisation colours up to iron grey and grey white. This condition is most evident in some of the segregated patches when in addition a curious perthitic intergrowth with ilmenite is evident. It is here found to pass out into occasional basic felspar laths, and the assumption is that the remainder of the crystallised ground mass is felspar.

Vesicles in this rock are filled mostly with a carbonate, probably calcite. The carbonate could well be dolomite, especially as rhombs of this carbonate have been seen in sections from the rocks from other mines. Occasionally rods of a fibrous carbonate, arragonite or fibrous calcite, can be seen under the high power lining the edge of some of the vesicles. Rods of a fibrous zeolite, probably natrolite, are present. Analcite, in small isotropic cubes, has also been seen. Chalcedonic silica is present as a secondary mineral, and also crystallised silica as quartz. A vesicle filled with quartz is rimmed with a network of green prismatic crystals showing high polarisation colours and oblique extinction. Pleochroism, if any, is extremely faint, and the mineral looks like epidote, but has not got the extinction angle of epidote.

These characters, combined with its high basicity and chemical composition, and its mode of occurrence as a dyke, are sufficient to place the rock among the monchiquites. The felspar is too insignificant in quantity to displace it from this monchiquite group.

Dr. Howitt (3) has described a dyke rock apparently similar to the above, from Lansell's 180 Mine, on the New Chum line, and named it limburgite. Mügge (3) in a review of Dr. Howitt's paper, suggested that the name monchiquite should be used to agree with the mode of occurrence, and the name limburgite should be reserved for very basic lava flows. This is the proper interpretation of the terms, and therefore we may call our type rock monchiquite.

An examination of a number of sections of lavas from other mines reveals the same general characteristics of the monchiquite group, with minor variations. A complete comparison is not possible, because the lavas are so frequently decomposed. This decomposition is in no way proportional to the depth below the surface, as shown by the Central Red, White and Blue rock. Further, the decomposition, once started, is surprisingly rapid. A lava, exposed only for six months at 2600 feet in the Koch's Pioneer was found to be crumbling in part, though quite dry. In the Pearl Mine a lava exposed some thirty years along the roof of a disused drive at 130 feet, has rotted sufficiently to form a linear heap of mullock along the floor of the drive.

In spite of this, fresh rocks, suitable for microscopical examination, were obtained from a number of places, and the following notes may be made:—Specimen No. 14, Lansell's 180 Mine, No. 2. The sample was obtained from the 400-foot level, about 30 feet south of the shaft. This mine is situated on the Sheepshead line, and adjoins the Central Red, White and Blue Mine. Three branches of the lava are present in this mine, while there are only two in the other. In this rock olivine has been more abundant, but is now completely serpentinised. Augite is present in two generations. The large augites are nearly colourless and sometimes zoned, sometimes with hourglass structure. The small augites form the same kind of network as in the Central Red, White and Blue rock. The hornblende is present in about the same proportion, but the ilmenite is relatively much less abundant. The colourless ground mass is in small proportion, but appears in the same residuum as patches, crowded with hornblende and ilmenite microlites. Vesicles are more developed, and this is always noticeable with the further decomposition of the rock as recorded by Dr. Howitt. Many of these have an inner core of green amorphous silica, rimmed with calcite, and the alteration is sometimes repeated.

Specimen No. 9, 3827-feet, Victoria Quartz Mine. The complete alteration of the olivine in this rock is very noticeable, and the ground mass is perfectly isotropic. This New Chum dyke was found to be very decomposed down to 1300 feet in the Pearl Mine, and very hard again in the Catherine Mine, Eaglehawk. Here the rock is similar to that in the Victoria Quartz Mine, but the vesicles are far more abundant, and many of them contain rims of a coarse fibrous carbonate, probably calcite.

Specimen No. 34, 1868-feet, Johnson's Reef Mine, No. 1. This is the Garden Gully lava, and here it is very dense, and the colourless ground mass is scarcely perceptible. Ilmenite is scarce, vesicles are numerous, and many are curiously lined with pyrite. The same dyke at the Clarence United Mine contains an average amount of ilmenite. Natrolite is well developed in the vesicles of this rock. The natrolite is prismatic, positive in sign, with straight extinction and low polarisation colours At the Koch's Pioneer Mine, the Garden Gully lava is not so fresh, but a section of a 2-foot dyke shows it to be relatively coarse. Olivine is completely serpentinised. Large augites are present, some of which have a core of inclusions. Ilmenite and hornblende are present in average proportions. Small biotites are noticeable. The ground mass is in general not isotropic, and consists mainly of a low polarising mineral. This is probably original felspar, but may be secondary, and developed during the alteration of the rock.

The rocks from the places above mentioned come within the monchiquite group, from which the following deviate:—

Specimen No. 7, Goldfield's Mine, No. I. The Goldfield's No. 1. is an abandoned shaft at the southern end of the Nell Gwynne line of reef. The specimen was obtained from the dump, and was a piece of a thick lava met in sinking the shaft at the depth of about eighty feet. The first glance under the microscope shows the rock to be generally similar to the true monchiquites. Olivine phenocrysts are partly fresh, and only partly serpentinised. There is only one generation of augite. The ilmenite is very abundant and hornblende is present. Biotite is present in relatively large crystals. The feature of the rock is that the ground mass is perfectly clear and colourless, and not isotropic. A large vesicle is present in the slide, and contains a little biotite and a great deal of calcite, and these are mixed with a mineral which is apparently identical with the true ground mass of the rock. Here it is found to possess cleavage, and an extinction of three or four degrees. It is untwinned and the polarisation colours are never above greyish-white. It is biaxial and positive, and has a refractive index less than that of oil of cloves (1.5333). Its appearance is that of a felspar, and its refractive index is that of orthoclase and anorthoclase. In addition it has in some places an appearance suggestive of very fine lamellar twinning, and one is therefore inclined to call it anorthoclase. It is probable that the chemical composition of the rock is not far different from the Central Red, White and Blue type, where the soda is in excess of the potash, and this assists the determination as anorthoclase. The presence of this anorthoclase (?) base distinguishes the rock from the typical monchiquites.

Specimen No. 5, Forbes Carshalton Mine. The specimen was obtained from the dump heap without any knowledge of its depth in the mine. The locality is more than one mile north of the Goldfields No. 1 shaft. Like the Goldfields' rock this rock is generally similar to the monchiquites. Olivine is mostly serpentinised, and the augite is present in two generations. Hornblende and ilmenite are perhaps in smaller proportion than in the typical monchiquite. These minerals are all set in a ground mass of felspar laths. The felspar shows lamellar twinning, and the lamellae give extinction angles up to 35 degrees, which determines it as labradorite. This felspar is present in much the same proportion as the isotropic material in the type monchiquite. In addition it appears on the segregation patches similar to the light coloured, acid residual areas in the monchiquite. Clearly this felspar has been the last mineral to crystallise during the consolidation of the magma, and in this respect it is certainly analogous to the isotropic material of the monchiquite.

The felspar of this rock and of the Goldfields No. 1 indicates that they belong to the camptonitic variety of lamprophyre. The Forbes Carshalton specimen is more of a true camptonite than the Goldfields No. 1 sample, with its alkali felspar. It seems to be very similar to a rock found at Balwyn, which occurred as a small flow. This has been described by Messrs. Chapman and Thiele (10) as a limburgite.

The examination suggests that the labradorite and anorthoclase are but further stages in the crystallisatiaon of the monchiquite magma. The distribution of each as a base for the other minerals is very similar, and their relative proportions are much the same. This, combined with the minute amount of felspar in the monchiquite itself, suggests the passage from the true monchiquite through the Goldfields No. I. type to the Forbes Carshalton type. The specific gravities of the two last-named are greater than the specific gravity of the Central Red, White and Blue type. This is in accordance with the suggestion because the specific gravity of a glass is always less than that of the mineral which would result from it.

Specimen No. 38. One Tree Hill Mine. (Plate I., Fig. 2). This specimen was collected by Mr. Whitelaw, and was obtained from a now inaccessible part of the One Tree Hill Mine, two miles to the S.S.W. of Bendigo. The One Tree Hill anticlinal axis is some distance to the east of the main lines of reef. In the hand specimen it is a hard, greenish rock with shiny flakes of mica. Microscopically, the rock is much altered and of porphyritic character. The outstanding phenocrysts are those of an originally well crystallised mineral, which is now completely altered to brownish unrecognisable material, though here and there small patches have only gone as far as chlorite and calcite. Some of these well bounded sections are eight-sided, and indicate original augite. Others are six-sided, and by their prism angle indicate original hornblende. No unaltered augite or hornblende is present. Plagioclase felspar occurs sparingly as crystals which are not much altered. Phenocrysts of biotite with ragged edges are common, with pleochroism varying from a deep brown to a very pale straw colour. It has undergone considerable alteration to chlorite. Some crystals of biotite have undergone internal bleaching, the iron having been leached from the centre, and concentrated in a ring which now gives a dark border to an interior of chlorite and calcite. Quartz is abundant, and the chlorite and calcite extremely so. Ilmenite occurs scattered in very small crystals, and apatite is also accessory in fine needles.

The rock is a typical mica lamprophyre, and, if placed in Rosenbusch's classification, it would be termed kersantite.

The specific gravities of these rocks were determined from small fragments, and found to be :—

Central Red, White and Blue sample - - -	2.95
Forbes Carshalton sample - - - - -	2.99
Goldfields No. I. sample - - - - -	3.05
One Tree Hill sample - - - - - -	2.78

Age of the Bendigo Dykes.

The dykes include ordovician sediments, and are certainly post-ordovician. South of the Big Hill tunnel, a monchiquite dyke cuts a granitic dyke. The granitic dyke is probably associated with the Harcourt granite, and the monchiquites are probably post-devonian. At Kangaroo Flat a dyke is found cutting through a glacial conglomerate. If this conglomerate is part of the derrinal series, and of permo-carboniferous age, the dykes must be later than permo-carboniferous. Further than this the stratigraphy of the Bendigo district cannot help one, for no later geological period has left its record except in some tertiary and recent river gravels.

No structural evidence is forthcoming, though there is a possibility that the relations of the dykes to the series of earth movements that have affected the Bendigo field may be found and co-ordinated in time with general movements throughout Victoria.

For further help we must therefore depend on the less convincing petrological evidences. Rickard (5) looked upon the monchiquites as part of the newer basalts. The monchiquites, however, are quite different from the newer basalt type, and are even more basic than the older basalt series.

The nearest petrographical allies are found in some limited ultra-basic lava flows in the Macedon district, e.g., King's Quarry type. Professor Skeats and Mr. Summers (11) have placed these flows near the top of Macedon series of tertiary igneous rocks. They have suggested the existence of a sub-alkaline magma beneath the whole of Victoria in tertiary times, and progressive differentiation from it has produced first the alkaline rocks and later the basic rocks. If this is correct and the King's Quarry type is a differentiation product from this magma, then the monchiquite dykes may well be its differentiation products also, because the monchiquite itself is a sub-alkaline rock. This analogy suggests that the monchiquites are of mid-kainozoic age.

Monchiquites are known to occur in a similar manner in other parts of Victoria.

Correlative evidence may therefore be produced in the future, but till then the balance of evidence, such as it is, leans towards the conclusion that these dykes were intruded in mid-kainozoic times.

Relation of the "Lavas" to the Gold Distribution.

Only a study over an extended period of time can throw much light on this question. Concrete cases, nowadays, of lavas in contact with rich gold-bearing stone are rare, and many such instances must be found and examined before the problem can be thoroughly discussed. Instances were probably not so rare during the earlier history of the field when all the development work was in the shallower levels, and it is more often the miner of the old days who asserts that the lava exerts an influence on the gold. There can be no doubt that such belief would be assisted by the presence of the lavas in centre country, and the lavas have been followed as guides to the unrecognised centre country. Such is obvious in mines like the Pearl, where drives in each successive level have been started on the lava.

My contribution to this question is the record of observations in the Ironbark Mine, Long Gully. Here, in sinking a winze in the centre country of the Sheepshead line from the end of a crosscut about 700 feet long at the 480-foot level, a lava was found to split into two branches, each about ten inches wide. The branches opened to about four feet, and then continued more or less parallel. The lavas are the dark, dense characteristic monchiquite, with streaks and segregations of olivine altered to serpentine. The enclosed space was filled with quartz. The winze was down twenty-seven feet at the time of my first visit, and the quartz across its full width showed galena, blende, and pyrite with just occasional colours of gold. Scattered through the milk-white quartz were dark fragments of the country rock, angular in shape, of all sizes, and with definite, unabsorbed boundaries found in fissure filled reefs. Between this reef and the dykes there is thoroughly brecciated material, consisting of pieces of slate, reef quartz and lava. Some of the quartz has lost the milky appearance and become vitreous, and there are greenish patches near the lava pieces coloured by the serpentinous material. This material is typical breccia, mineralised, and very rich in gold.

Pieces broken from right in the side of both lavas showed gold. Mr. Rogers, the manager, gave me a piece of the eastern of the two branches, showing a coarse shot of gold quite obviously detached from any quartz whatever. Examination with a pocket lens showed that the rock immediately around the gold was different from the main mass of monchiquite.

A thin slice of this rock, cut through visible gold a little distance from the one coarse shot, was prepared, and revealed the fact that the rock actually containing the gold itself was a piece of breccia set in the dyke material. The bulk of the gold is mixed with dark, opaque material, which looks decidedly carbonaceous. This dark patch also contains small pieces of a white micaceous mineral, calcite and slaty material. One fragment of gold is detached from the opaque material and set in a lump of fine sandstone, but has several veins of secondary calcite leading up to it. The whole is surrounded by fragments of micaceous slate and sandstone. These fragments have apparently been caught up by the lava in its intrusion, and cemented well into the lava during consolidation. The detached fragments of lava in the breccia indicate earth movements subsequent to the consolidation of the lava. These may have followed the consolidation immediately, resulting from the same rock stresses involved in the intrusion itself.

A thin slice (Plate I., Fig. 2) of another specimen of the contact material was prepared, cut transversely to the contact, and through visible gold. This section clearly shows crustification parallel to the direction of the lava. The gold in the hand specimen could be distinctly seen lying between crustified bands for a length of about four millimetres before the slice was cut. Under the microscope, pieces of slate, galena, and opaque material are seen between the crustified bands. Mixed with the opaque matter and also with the galena is gold. As before, the opaque matter looks decidedly carbonaceous. This crustification clearly shows that mineral-bearing siliceous and calcareous solutions have traversed the side of the lava, subsequent to the lava. The presence of carbonaceous material suggests that it was the precipitant of the gold.

Connected with this is the fact that the bulk of the gold is in the brecciated material, which would itself certainly provide the easiest passage for solutions. This is evidence which points to the conclusion that the gold is secondary, meaning by this that the gold is subsequent to the reef, that the gold has been deposited elsewhere first, from there removed, and re-deposited in this breccia, and that therefore there has been secondary enrichment in this particular spot.

A drive was opened to the south from this winze for about a hundred feet, and a second winze is being sunk. In this winze the lavas are six feet apart, but the whole of the space between is not filled with quartz. It is in part slate, and the reef, about three and a-half feet wide, pursues a wavy course downwards. Occasional colours of gold, I was informed, are seen throughout the reef, but the brecciated material seemed to be absent. The reef in this winze is not nearly so rich as the No. I. winze, and this erratic distribution supports the conclusion of secondary enrichment.

The lavas may influence the gold distribution in the following ways:—

(1) The heat accompanying the intrusions may stimulate the flow of the underground solutions involved in the formation of the quartz reefs.

(2) The lava sheets may act as an inpervious barrier to the transverse passage of such solutions.

(3) The lavas may form drainage channels for the vertical passage of such solutions.

(4) The dyke material may act as a precipitating agent to the gold carried by traversing solutions.

If the lavas are of the late geological date indicated by the petrological evidence, the first of these methods has had no effect on the primary deposition of the gold. Observations where the dykes cut through reefs at the deeper levels, as at 2300 feet in the Catherine Mine, Eaglehawk, and at 2600 feet in the Koch's Pioneer, Long Gully, are all negative, yielding no evidence of any influence on the gold distribution. Such influence would be noticeable, if anywhere, in the deepest levels, where the heat and stimulation would be greatest and it is becoming generally recognised that the deeper reefs are not so valuable as the shallower reefs.

If the second method operated, one would expect enrichment only on one side of a lava, cutting through a reef, and I have found no evidence in this direction.

The third method is one which I venture to suggest in explanation of the above Ironbark occurrence. The evidence points to the circulation of gold-bearing solutions subsequent to the reef, and to the lava. The evidence is not sufficient to decide whether the solutions came from above or below. Circulation of solutions may operate throughout the whole field, but for enrichment it is necessary that:—

(1) The solutions should traverse the dyke channel.

(2) The solutions should be gold-bearing.

(3 The solutions should meet material which will precipitate the gold.

Only where these three conditions meet will enrichment result. Enrichment will thus not necessarily result when a decomposed dyke meets a quartz reef or spur. If the enriching solutions are travelling downwards, enrichment is only likely in the shallower levels of any mine.

The fourth possible method is suggested by the example recorded by Mr. Dunn (2) in the Hercules and Energetic Mine, where a quartz spur cut through the dyke, and is rich in the dyke and poor on each side. No evidence has been produced to show how the dyke could possibly so operate.

In concluding this paper I should like to acknowledge the invaluable assistance of Mr. T. W. Ross, B.M.E., Assistant Inspector of Mines, in gaining for me access to the mines, and of Mr. H. S. Whitelaw and the members of his staff, and by no means least the unfailing courtesy of the mining managers. In the laboratory I have been much indebted to Professor Skeats and Mr. Summers, M.Sc. To Mr. H. S. Grayson I am especially indebted for the preparation and staining of rock slides.

Summary.

The dykes of the Bendigo goldfield are intruded into folded ordovician rocks. They form a parallel system with a parallelism coincident with the strike of the rocks. They occur along the course of each anticline, and in the mines are always approximately in the centre country. At the surface they are always decomposed and soft.

Specimens of fresh lava were obtained from several of the mines. These were examined, and one was analysed. The rock was found to be highly basic, and a member of the monchiquite group. The monchiquite was found to pass into camptonitic varieties at the Forbes Carshalton Mine, and at the Goldfields No. 1 shaft. A kersantite is recorded from the One Tree Hill Mine to the south-west of Bendigo.

The age of the rocks can only be determined by petrological analogy, and is considered to be probably mid-kainozoic.

The relation of the lavas to the distribution of the gold is discussed. Evidence has been obtained in the Ironbark Mine to suggest the secondary deposition of the gold. Gold is found more abundantly and irregularly in thoroughly brecciated material than in the adjoining

reef quartz. Some of this gold was examined microscopically in thin section, and was found to be in crustified bands along the side of the lava. Hence the lavas are believed to influence the deposition of gold only in so far as they provide drainage channels for the flow of secondary mineralising solutions.

Literature.

1. Gregory, J. W.— Contributions to the Bibliography of the Economic Geology of Victoria. Rec. Geol. Sur. Vic., Vol. II., Pt. 3, 1907.
2. Dunn, E. J.—Reports on the Bendigo Gold Field, Nos. I. and II. Special Rep. Dept. Mines, Vic., 1896.
3. Howitt, A. W.—Notes on Samples of Rock Collected in the 180 Mine at Bendigo. Special Rep. Dept. Mines, Vic., 1893.
4. Mügge, O.—Neues Jahrb., Min. Geol., 1894, Vol. II., p. 271.
5 Rickard, T. A.—Origin of the Gold Bearing Quartz of the Bendigo Reefs, Australia. Trans. Amer. Inst. Min. Eng., XXII., pp. 289-320.
6. Argall, F.—The Dykes and Reefs of Bendigo. Trans. Amer. Inst. Min. Eng., XXIV, pp. 933-942, 1894.
7. Whitelaw, H. S.—The Northern Bendigo and Raywood Goldfield. Rec. Geol. Surv. Vic., Bull. No. 12, 1904
8. Harper, A.—The Natural History of Igneous Rocks. Metheun and Co., p. 12.
9. Maclaren, J. Malcolm.—Gold, its Geological Occurrence and Geographical Distribution, p. 367.
10. Chapman, F., and Thiele, A. O.—On a Limburgite Rock Occurring as a Plug at Balwyn, near Doncaster. Proc. Roy. Soc. Vic., Vol. XXIV. (new series), Part I., p. 124.
11. E. W. Skeats and H. S. Summers.—The Geology and Petrology of the Macedon District. Bull. 24, Geol. Surv. of Victoria (in the press).

DESCRIPTION OF PLATE I.

Fig. 1.—Monchiquite; 318-foot level, Central Red, White and Blue Mine, Bendigo. × 35.

Fig. 2.—Kersantite; One Tree Hill Mine, Bendigo. × 25.